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Summary of PM Workgroup call of November 16, 2020 on dilution tunnel mixing issues

Workgroup Participants:
Allen Robinson, Carnegie Mellon University
Jay Turner, Washington University of St. Louis
John Watson, DRI
Eric Dithrich, AirTox Environmental
Phil Hopke, Clarkson University (emeritus)

Also on the call:
Stef Johnson, EPA/OAQPS, MTG
Lisa Rector, NESCAUM

Facilitator: George Allen, NESCAUM

George thanked participants for their continued participation in this workgroup process, and noted that Jamie Schauer was unable to participate. Eric Dithrich, a principal with Air Tox Environmental with source testing experience, participated in these discussions. As background information, George showed an example of time-resolved PM gradients in a dilution tunnel that is compliant with ASTM 2515, as measured by a pair of TEOMs; inlets were both within the two-inch centroid required by the test method and at the same elevation. Compared to available information on different tunnel configurations at EPA certified RWH test labs, this tunnel was larger, with a ten foot long 12 inch diameter "mixing section", but still exhibited non-uniform PM at the sampling point.

The call roughly followed the suggested topics in the November 12 meeting memo. George asked the group if larger dimensions, wider diameter, longer residence times would help with mixing. Phil noted that larger dimensions would tend to allow more mixing. Possible issues with the final 90 degree elbow into the down-tube were mentioned. Eric asked about possible interference between the multiple inlets. George noted that flow was very low, 0.5 lpm relative to the velocity of tunnel flow. John noted that he'd expect the mixing to be highly variable over time and thus average out [this is not what we see]. Phil noted that the literature on fluid dynamics suggests that downstream from a bend spatial, differences can persist longer than expected.

George noted that the final elbow could be changed to have a much larger bend radius by using multiple smaller angle elbow pieces. This, along with keeping the diameter the same (eg, not reducing it as required by ASTM 2515) would provide additional mixing. Phil noted that CFD would be useful in evaluating these kinds of design changes. Jay noted a paper that looked at effects of a 90 deg. elbow downstream, noting CFD modeling showing dramatic downstream turbulent flow separation but only to a couple of pipe diameters downstream.
Dutta, [HYPERLINK "http://dx.doi.org/10.1016/j.jestch.2015.12.005"]

The group was asked about the existing ASTM 30 ft length limit, and no one noted that a longer length might be an issue other than additional cost and space requirements.

Flow straighteners, baffles, etc for mixing were discussed. Phil mentioned that a Sterman disk with rounded surfaces would breakup flow lines and minimize accumulation of particles. If baffles were used, they could be angled rather than at 90 degrees to the flow [or even rounded surface baffles?] to minimize particle loss. Eric and others expressed concern about particle loss on baffles or other turbulence-inducing structures.

Alternatives to Pitot tubes for tunnel velocity traverses with lower velocities were discussed. Phil suggested hot film [not wire] anemometers would be better suited to use with high particle loading. However on checking, the current method measures tunnel velocities only when there is no device under test – a clean flow, and hot wire anemometers are more widely available and less expensive.

For verifying proper mixing, the group agreed that using an inert gas like CO instead of an actual combustion test was not going to be sufficient to demonstrate good mixing.

John Watson suggested using optical particle counters to verify mixing; these could be used when the burn is dirty, but when the burn is clean the size is too small for optical sensing. He also noted their use of a thick screen or mesh prior to the mixing/aging section to promote mixing / flow straightening as described in Chang et al., J. Air & Waste Manage. Assoc. 54:1494–1505, which also says 10 seconds aging was needed to achieve stable particle size and number.

Should labs be required to demonstrate mixing? Phil: Performance vs. design standard - he prefers performance standard. Allen: only run tunnel at whatever flow it was certified at. Eric: mixing must be verified; there is value in having required elements for mixing in a tunnel design. Eric: vanes, baffles, screens are problematic in term of particle buildup.

Stef noted that ISO 25597 has a +/- 10% stratification standard (Section 6.2.3.1). An optical pm imaging approach could be used; traversing Teoms should work well. Diluant traverse as a performance check could be done each time a test was run. For mixing measurements during a test CO is too variable; CO2 might be better.

There was a general consensus that CFD should be used for this purpose. George requested that WG members send him any ideas as to how CFD could be used to inform mixing in a new tunnel design, and for suggestions on who might be able to do this kind of CFD modeling.

Phil noted that FLUENT may not be well suited for this high-turbulence scenario. Jay suggested it would be worth talking with Max Zhang at Cornell, although most of his work is with building downwash, and what we are looking for is someone who does pipe-flow CFD. Jay agreed with Phil that FLUENT is probably not useful for the highly turbulent conditions we have in these tunnels.

George thanked the group for their participation and asked members to send names for CFD and pointers to any relevant publications on turbulent pipe mixing.

Additional information.

NESCAUM is contracting with Satbir Singh at CMU (thank you Allen!) to do initial CFD modeling on the base case with a much larger mixing section (diameter and length). If that doesn't provide sufficient mixing by the end of the horizontal mixing section, some kind of flow-line disruption will be needed – either ribs or some version of a Sterman disk (thank you Phil!).

Additional discussions with Phil and Mark Champion (HLS) were about using a modified Sterman disk to disrupt flow lines. Instead of a flat disk, a N-sided pyramid could be used. This might be useful at the end of the hood section where the stack and makeup air mix before the first elbow section, and would split the stack flow into a much more dispersed pattern to mix with the makeup air. Comments on this or other approaches are welcome.